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ABSTRACT

Most recent research on the impact of the new computer technology on skills has been focused on developing arguments that either support or contradict the "deskilling" thesis put forth by some economists and sociologists in the mid- and late 1970s. Although this research remains inconclusive, some generalizations can be suggested. The research shows that at least in the large core firms in both manufacturing and services, microelectronics is eliminating rather than increasing the lowest skilled jobs. An example from banking also supports findings that microelectronics enables the broadening of skill requirements for middle-level jobs, while the introduction of computer-based technology leads to greater specialization of upper-level and managerial personnel. Surprisingly, however, the large body of research on employment and technology has little to say about the impact of microelectronic technology on the process of skill formation. Evidence from a study of banking indicates, however, that in this industry at least, the processes of skill formation are undergoing a major transformation, suggesting both an increasing role for outside educational preparation and more firm-based training for highly specific objectives. In order to allow for further research, a framework can be suggested emphasizing the relationship between the development and diffusion of the new technology and the availability of skilled labor, the uncertainty in labor supply and the firm's markets, and the institutional and social factors that shape the firm's response. (KC)

NEW TECHNOLOGY AND SKILL FORMATION: ISSUES AND HYPOTHESES

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PREFACE

The National Center on Education and Employment is funded by the Office of Educational Research and Improvement (OERI) of the U.S. Department of Education. The Center is based at Teachers College, Columbia University, in New York City. The RAND Corporation of Santa Monica, California, and Washington, D.C., is a partner with Teachers College in this enterprise.

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Introduction

The last two decades have seen significant changes in the nature of work and skills in the United States. These changes have resulted from many factors including the diffusion of computers and related microelectronic technologies, the shift from manufacturing to service industries, internationalization of the U.S. economy, and deregulation. Together these developments have acted to change markets, have put pressure on firms to adjust their human resource strategies, have contributed to a shift from blue collar to white collar work, and have altered the nature of many skills.

Traditional patterns of skill formation are now breaking down, and new ones forming based on different interactions. In particular, recent developments suggest that the mix between outside schooling and employer-based training is undergoing a significant transformation. Nevertheless, although the impact of structural, especially technological, changes on employment has attracted a great deal of attention, most analysts have focused on changes in skills and work organization; few have carried the analysis further and asked how the skill preparation system has reacted or should react to these developments.

This paper is a first attempt to identify and understand how changes in the structure and nature of skills are affecting the process of skill formation and, in particular, the balance of training and preparatory responsibilities between firms and the education system. It concentrates on the impact of micro-electronic technologies.

The first section discusses the historical and economic context within which computer-based technology has been introduced, and establishes some important distinctions between an earlier phase of computerization dominated by the introduction of mainframe computer-based systems and the current one characterized by on-line systems, robots, mini- and micro-computers. The second section discusses findings from the research literature concerning the impact of

computer-based technology on skills and skill formation. This section concludes that while there is a vast literature on the impact of micro electronic technology on work organization and skills, there is surprisingly little on the implications for skill formation. The third section identifies some of the linkages between skill changes and changes in skill formation using examples from the banking sector. The fourth section draws on the findings from the previous sections and the more traditional labor market literature to develop a conceptual framework for understanding the changes in skill formation resulting from the introduction of new technology. The paper is summarized in the last section.

The Age of Micro-Electronic Technology

Current changes in employment and labor force training processes are taking place in the context of profound changes in the production system. In The Second Industrial Divide (1984), Michael Piore and Charles Sabel have argued that the age of mass production, characterized by the production of large manufacturing runs of standardized goods by giant corporations is coming to an end. What appears to be replacing the mass production economy is one characterized by more competition, shorter run production, greater diversity, and faster changes in the output of both manufacturing and service industries.

Piore and Sabel's analyses, which take their cues from examples of manufacturing renaissance in advanced economies, are consistent with those of other social scientists who have investigated the rise of a "post industrial" society (Bell, 1973) and the shift to a "service" economy (Stanback et al., 1981). Each, in his own conceptual terms, argues that the era of mass production is being superseded by that of customized production in which producers of both goods and services must strive to meet the demand of increasingly splintered and segmented markets. To a large extent this shift is being achieved through a growing use of service inputs in the production process, enabling

producers to better understand market demand (through more extensive market research), to better respond to it (through increasing use of engineering, systems design and similar services to produce more flexible production processes), and to penetrate further markets (through more intensive communications and advertising).

Together, these analyses are also consistent with the observation that, for nearly two decades now, net employment growth in the U.S. has been overwhelmingly in service firms and white collar and service occupations. This does not imply that production of manufacturing goods has declined across the board (even though this has been the case in a few sectors, such as steel), simply that goods production requires much more "service" or "service-like" inputs, and less "blue-collar like" inputs.

Micro-electronics is playing a critical role both in creating the technological and market conditions that have caused the new era of customized production and segmented markets, and in helping firms adapt to the new circumstances. But that role has changed over the 40 years since the computer's introduction. It is particularly important to distinguish the new era of distributed data processing from the earlier one dominated by mainframe computers (Ginzberg et al., 1986, Chapter 1).

The first stage of commercial computer technology, beginning in the mid- and late-1950s, involved mainframe computers that performed high volume calculations at great speed and low costs. This new capability increased productivity dramatically in many administrative functions, especially those with a heavy clerical content, such as recordkeeping, order taking, billing, and accounting.

Mainframe technology generated a demand for specialized personnel, primarily system engineers and analysts, programmers, computer operators, and key punchers. This specialized labor was employed in centralized systems divisions that developed applications and processed

the data for users. In most departments, the impact of the computers on the work process was felt only through any work reorganization that was necessary to prepare the data for centralized computer processing.

By comparison, the new phase of computerization, often loosely identified as the phase of distributed data processing, involves a decentralization of computing power and results in a more direct impact on user departments. Distributed data processing systems make extensive use of on-line technology, robots, mini- and micro-computers and create linkages among firms, and between firms and customers, through enhanced communications systems. More importantly, however, distributed data processing blurs the old distinctions between personnel specialized in the use of computers and users of computer services, since user departments are now involved directly in processing information and data. Thus, more than ever before, the new technology can be used to effect critical changes in traditional institutional arrangements, including those affecting the division of labor, organizational structures, and skill requirements at all levels of the occupational hierarchy.

At the same time, through its effect on markets, communications, and production processes, the new technology is changing the roles of firms, industries, regions, and even countries, and the interactions among them. Indeed, many of the broader structural changes affecting employment, such as the growth of services and international competition and deregulation, are themselves partly caused by the introduction and diffusion of microelectronics. The new systems are helping to reshape old products and develop new ones; restructure and create new markets; redistribute organizational power and responsibilities; develop new linkages among distribution, production and R&D functions; and reorganize the work process. In short, they are leading to new, more flexible, institutional arrangements that meet the demands of the new era of flexible production and segmented consumption.

The Impact of Micro-Electronics on Skills and Training: Conclusions from the Literature

The Changing Nature of Skills. The debate over the impact of computer technology on the nature of skills and work organization has by now generated hundreds of studies. Much of the research has revolved around the upskilling/downskilling debate. Like many seemingly technical controversies in the social sciences, this debate reflects fundamentally different views about the nature and direction of advanced societies and economies.

The controversy is set out in two of the seminal works in this area. On the one hand, Daniel Bell's (1973) conception of the "post-industrial society" was extremely optimistic. He believed that new technology would virtually eliminate tedious manual work, and the economy would move towards one in which knowledge and information would be the central component of most activities. Bell argued that production of basic necessities would require less time and resources, and that there would be a much greater emphasis on recreation, education, the arts, and other amenities. Harry Braverman (1974) attacked this conception of society, arguing that new technology was being used for precisely the opposite process--the further separation of the conception of work from production itself and the creation of a large number of jobs devoid of skills or control. Braverman did not argue that this was a development inherent in the technology itself, but rather in the uses made of the technology by the owners of capital and their managers.

With nuances, the controversy lives on. Thus Paul Adler (1984) and Larry Hirschhorn (1984) have both suggested that new technology has allowed a reintegration of previously fragmented work and has led to the need for a more highly skilled work force. Piore and Sabel (1984) have argued that the new technology is one of the factors that creates opportunities for "flexible specialization" in production, using programmable technology and broadly skilled workers in a process that

is reminiscent of nineteenth century craft production rather than twentieth century mass production. On the other hand, Harley Shaiken, Stephen Herzenberg and Sarah Kuhn conclude that in introducing new technology in machine shops, managers "...attempted to remove planning responsibility from the shop floor more often than they tried to combine flexible technology with broadly skilled workers" (1986; p. 181). In an article on computer programmers, Philip Kraft and Stephen Dubnoff conclude that "software work replicates rather than revolutionizes traditional relationships between managers and the managed" (1986; p. 194).

The research on which the controversy is based can be divided into aggregate studies based on national data sets--usually the Dictionary of Occupational Titles (DOT), the Decennial Census or the Current Population Survey--and case studies based on analyses of firms, industries, or occupations. Both strands of the literature have recently been reviewed by several analysts. (See Baran and Parsons, 1986; Bertrand and Noyelle, 1985; Flynn, 1988; Levin and Rumberger, 1986; and Spenner, 1985).

Most aggregate studies try to assess the extent of upskilling or downskilling by combining measures of aggregate occupational shifts in the labor force the measures of change in the skill content of major occupations. In his review of such studies, Spenner (1985) argues that most studies reveal very little change in skill levels. The moderate changes that do emerge appear to be more consistent with the upskilling than the downskilling hypothesis.

The biggest problem with the aggregate studies concerns skill measurement (Baran and Parsons, 1986; Miller et al., 1980; Spenner, 1983). Neither the DOT's list of occupations nor its occupational definitions have been fully updated. Hence, many of the newest occupations or suboccupations are simply missing, and between three-quarters and four-fifths of the descriptions are identical in the last two editions (Cain and Treiman, 1981). The decennial census is

conceptually an even weaker data set than the DOT, since changes in skill requirements can only be inferred from changes in educational level and in occupational earnings.

Not surprisingly, case studies generate greater concrete insights about the effects of the introduction and use of new technology than aggregate studies do. Taken as a whole, however, case studies are not conclusive, both because of problem in generalizing findings and because of seemingly conflicting results.

For example, some case studies of machine shops have found downskilling and work fragmentation (Braverman, 1974; Noble, 1977, 1984; Shaiken, 1984; and Shaiken, et.al., 1986), while others have found downskilling followed by reintegration and broadening of skills (See Baran and Parsons, 1986, for a discussion of these studies). Studies of office automation have also come down on both sides, although mostly on the upskilling side (Bertrand and Noyelle, 1985). Braverman's (1984) description of the early development of data processing and Evelyn Glenn and Roslyn Feldberg's (1977) study of white collar work in five industries found deskilling in clerical work, while Adler (1984), Hirschhorn (1984) and many others (see reference in Bertrand and Noyelle, 1985) find cases of reintegrated and broadened white collar work.

These conclusions appear contradictory. Nevertheless, the discussion of the stages of diffusion of micro-electronics and of the potential scope of its impact presented in the first part of this paper can help sort out the results of the various studies.

For example, given that the impact of computer technologies permeates the entire economy, case studies that focus on a narrow unit of analysis such as a firm, an industry, or an occupation are difficult to generalize. The problem is particularly serious with case study research because of the tendency for analysts to concentrate on a few industries and occupations. In manufacturing, for example, the

research on numerical control has been extremely influential. For that matter, the influence of the new technology on the skills required by machinists is almost the paradigmatic example for the proponents of the "deskilling" argument. But there were only about 300,000 experienced machinists in the country in 1970--less than one half of one percent of the experienced civilian labor force. All metalworking crafts workers put together (about 1 million) barely surpassed the number of waiters and waitresses that year. Likewise, the office automation studies have concentrated on industries dominated by large bureaucracies--white collar factories--such as banking and insurance.

Another problem concerning the unit of analysis is that the technology may be shifting the location of skills in ways not picked up by case study research. Despite the divergent results, the case studies do suggest that the large organizations that are usually the subject of these studies are no longer the locus of large numbers of jobs for illiterates or for high school dropouts. Yet, this shift may reflect increasing reliance by large firms on outside subcontractors with a different skill configuration than the central firms. If that is the case, then most firm-based research is simply missing an important effect of the new technology. Likewise, it may be that the new technology, along with general economic growth, are resulting in upskilling in the core industries in both manufacturing and services, but generating simultaneously the growth of large numbers of low skilled jobs in peripheral industries (Levin and Rumberger, 1986).

The distinction between the earlier and later eras of micro-electronic technologies also provides a key to understanding the research on skill changes. The notion that technology affects skills differently according to stages in its diffusion is consistent with examples from the introduction of numerical control and advanced computerization among white collar occupations.

Initially, brand new technologies and processes require a small cadre of highly skilled workers and engineers. The development of

computers described by Braverman (1974) is one example, and the initial stages of the use of numerical control is another. The technology is then incorporated into established processes used in mass production, at which point the skill requirements fall--as happened with the use of mainframe computers by the large insurance companies or the diffusion of numerical control.

If we come to view this earlier stage of computerization as that at which developments come to rest, as Braverman and other researchers did, then the outcome of change is bleak. But recent studies contradict those views and argue that further developments in micro-electronics, and perhaps other factors as well, are being used to move beyond the early stage. In particular, such studies indicate that the diffusion of micro-computers and programmable technologies is helping to reintegrate previously fragmented work in both machine shops (see Sabel, 1982, Piore and Sabel, 1984) and white collar settings (see Adler, 1984; Hirschhorn, 1984; Noyelle, 1986). Thus the overall transformation may involve consecutively a "downskilling" and an "upskilling."

The concept of stages can also help in understanding how the results of aggregate studies and of case studies are related. Since at any given time there are a variety of new technologies and processes at different stages of development and applications, then aggregate studies may find little overall effect as different stages offset one another.

Based on our reading of the literature, we believe that the evidence does support some conclusions about skill changes. But it is significant that this vast literature, despite its many insights, yields so few generalizations.

First, it does not appear that massive deskilling in core firms, both in services and manufacturing, is taking place. Indeed, the lowest skilled jobs in these firms are disappearing. However, the

extent of the growth of unskilled employment in auxiliary occupations such as food service workers, security guards, janitors and so forth remains an open empirical question. Still, this development does not appear to be directly attributable to technological change, except perhaps to the extent that productivity growth resulting from new technologies promotes the growth of the demand for this type of service.

Second, the new technology does create the possibility that middle level workers increasingly will be called upon to perform a variety of tasks previously fragmented and performed by several workers, even though the nature of this trend and the dimensions along which the skills are changing may not yet be well understood.

Third, the rapid development and diffusion of new technologies does create a strong demand for a growing cadre of skilled technical and professional personnel.

The Changing Skill Formation Process. Recent research hints at major changes in the processes and structures through which skills are learned. On the one hand, there is evidence of an increased dependence on formal schooling for work-related training (Noyelle, 1986). On the other hand, Nell Eurich (1985) argues that there has been a proliferation of private sector training efforts. Focused as it is on the upskilling/ downskilling debate, the research on the employment impact of the new technology has shed little light on changes in skill formation. Neither has it sought to identify trends in training processes nor to develop the educational and training implications of the changes underway. While some basic messages emerge, often only implicitly, little guidance can be found in this vast literature. The arguments run roughly as follows.

If one subscribes to the deskilling thesis, the need for skill formation should be declining. Under such a scenario, educational institutions will need only to assure the continued generation of a

relatively small cadre of highly trained engineers, technicians, managers, and professionals. The large majority of jobs will require little schooling or training. Proponents of the deskilling view do not argue necessarily that education should be reduced (education is important at least for its own sake), but they may argue that the current trends will lead to a social problem caused by frustrated expectations of educated workers who can only find unskilled and unsatisfactory jobs. The policy prescription here is to argue for changes in the employment structure to make fuller use of the available and growing skilled labor force.

Under an upskilling scenario, the diffusion of new technology seems to call for increasingly higher levels of preparation, although who should be trained in what and by whom remains at issue.

If one argues that the employment changes brought about by technology are not that significant, then the skill preparation response need not be dramatic. As Spenner (1985) concludes:

> Rather than dramatic new forms of education and training, or more of all kinds of education for everyone, the evidence does provide grounds for the education enterprise doing what it already does better or in slightly different way and for more schooling for some of the population. (p. 147).

This research does not address the impact of technology, or indeed any other factors influencing skill requirements, on the process of skill formation or the balance between the educational system and the workplace in teaching skills needed on the job. In the next section, we present some preliminary findings for our early case interviews in the banking industry in order to develop some insights into changes in the training process.

Changing Skill Formation in the Banking Industry

The banking industry is experiencing many of the market and technological changes that are taking place in the economy as a whole. It has already found many applications for micro-electronics. Reflecting similar trends throughout the economy, computerization, linked to other developments, has resulted in a proliferation of products and services, increased customization, greater emphasis on dealing with customers, sharpened competition, rapid market shifts, and increased uncertainty. And although this example will not provide information about training for blue collar workers, banking does share some developments with manufacturing industries. The shift towards automation and high value-added production in manufacturing means that increasing shares of employment in manufacturing industries are accounted for by white-collar workers, whose work is subject to processes of rationalization and reorganization similar to those found in the banking industry.

Market and technological developments in banking are causing major changes in the traditional structure of skills and the entire process of skill formation is being reshaped as a result. This is affecting both the substance of the skill formation process--which class of workers is getting trained in what--and the locus of skill formation--the division of labor in the training process among the firm, the outside trainer, and the formal education system.

Increasing, computerization is leading to the elimination of a considerable amount of repetitive, routine, manual processing work that in the past supported the delivery of banking services. The handling of printed forms, paper based files, manual records, manual calculations and similar tasks had been the basis of many banking jobs. Computerization is affecting all workers although its most direct impact is on low level personnel (file clerks, messengers, low level statistical clerks, and similar personnel) by eliminating their raison

d'etre and shifting their functions to middle level personnel working with automated systems.

Middle level personnel are also taking on a broader array of functions. Increasing computerization of banking products is bringing together information once scattered among various employees and departments. As a result, many middle-level jobs traditionally oriented towards "order taking"--filling out forms to initiate the clerical production process--increasingly involve "serving"--providing customers with the various pieces of information necessary to provide the customized mix of services that will best answer their needs. Therefore many of the responsibilities associated with managing the interaction with customers are filtering down from upper tier to middle tier personnel. For example, a corporate account officer may now delegate much of the day-to-day interaction with corporate customers (money transfers, issuance of letters of credit and so forth) to a subordinate corporate service representative. One result of these changes is a shift toward finding better educated middle level workers who have a stronger capacity to comprehend both the bank's services and capabilities and the customer's needs, and a shift away from lesser educated clerks who worked primarily on specialized form-handling tasks.

In the upper occupational tier, a reverse shift is occurring. Where banks used to emphasize the need to train "generalist managers" who all knew something about many aspects of the banking business, and who were trained primarily to manage clerks who delivered the banking service, the new banking market puts an increasing emphasis on high-level specialists--accountants, system designers, marketers, product developers, bond traders and so forth--who develop the bank's products and market those complex services that only they are able to handle (merger and acquisition services, interest swaps, currency swaps etc.).

In the paragraphs that follow, we show how these changes are taking place in two banks. With each example, we emphasize only those transformations that seem best highlighted in that particular case.

Bank A. The first bank is a medium size bank in a major regional market center. The change in its hiring and human resource strategy is a good example of changes in middle level jobs brought about by the introduction of new technology and proliferation and diversification of consumer services--itself caused or at least enabled by the new technology.

These developments are particularly clear in the branch system which accounts for just under one-third of the bank's employees. In the past, the branches were very much a part of each neighborhood. Branch employees came from the neighborhood or its surroundings, which, typically, meant inner-city minority employees for downtown branches and white employees from bluecollar origins for other branches. This labor force was set in its habits, customs, and ways of relating to the outside world. However, the pattern was disrupted by the major shift in the city's employment base towards services with a concomitant gentrification of its population and neighborhoods.

By the early 1980s, the bank began to emphasize the new and very competitive upscale consumer market. First it adjusted the branch staffing pattern to the traffic pattern. Up until 1984, each branch employed about 10 to 12 full-time employees including three or four tellers, four to six customer service representatives (CSRs), one manager, and one assistant manager. Beginning in 1984 the bank attempted to make more extensive use of part-time employment by converting every full-time job opening in branches into two part-time jobs in order to staff peak-hours (11 to 3, Monday through Thursday; 11-to-close-of-business, on Friday).

The bank used the development of its peak-time shift to begin changing the skill preparation level of its branch personnel. Whereas

in the past most branch personnel had been hired at the high-school-or-less educational level, the bank advertised the jobs that it was opening for the peak-time shift to college educated women seeking part-time employment. Replacement hiring of full-time branch personnel has now undergone a similar shift in emphasis.

This change in hiring requirements came as a result of the bank's assessment that, to be successful in the new consumer market in which competition had intensified, products had multiplied, and consumers' sophistication had increased, it needed to shift from the bank's old emphasis on "order-taking" to a new emphasis on "selling."

The bank saw automated banking as a crucial element in the transformation of its branch business. In the early 1980s, the bank had started the introduction of automated teller machines (ATMs) and accelerated the development of its teller terminal automation program. In early 1986, the bank began a platform automation project. In its first phase, platform automation is intended to give CSRs access to on-line information on customers' accounts and transactions, later to allow them to open accounts directly on terminal based systems, and at an even later stage, to give them tools for financial planning for customers.

In the short term, the introduction of these automated systems turned out to be more difficult than first envisioned, partly because of the systems department's inexperience in developing user friendly systems. Nevertheless, the introduction of new technology has provided a base to expand dramatically the bank's product offering and to automate a large number of formerly paper-based transactions. But this new banking demands new branch employees who must now play a key role both in managing the bank's ongoing relationship with customers and in selling the bank's products. This is a major shift in the nature of once passive branch jobs, especially for a bank that is left with large numbers of its older employees. Branch employees must now have a capacity to understand both the customer's needs and the bank's

potential response, and to define both the problem and its solution. The bank management considers a two-year college education to be a minimum requirement for carrying out the problem-definition and problem-solving functions. The bank augments this basic education by providing training for product knowledge (ten years ago, consumer banking amounted to about five or six basic products; today the bank has several dozen products to offer), customer service, and sales skills, the latter two demanding mostly behavioral training.

The total of these changes is a sharp rise in both entry-level educational prerequisites and in-house training. Older, lesser educated employees are having great difficulty in coping with these changes, lacking both the education necessary for the required new, broader, systems-wide understanding and the skills needed to design financial packages for households or individuals.

Bank B. The second bank, also a medium sized institution, specializes in wholesale banking, that is in serving corporate clients. It provides a good example of the impact of the new technology on high level employees.

For many years, this bank benefited from almost exclusive access to a market niche comprised of a group of firms specialized in international trade. Recently, however, the bank's traditional market share in some areas started slipping. Beginning in the early 1980s, large corporate demand for commercial bank loans decreased dramatically as the corporations learned to handle their short-term needs by borrowing directly from the commercial paper market and to fund their long-term investment needs through capital rather than credit markets. Large corporate customers turned to banks increasingly for their "investment banking" services or for more and more specialized and complex transactional business, such as cash management services.

This bank tried to reposition itself by expanding its investment banking and cash management services and by seeking new business among

middle market firms which continue to need traditional commercial banking services. But this occurred in an environment in which competition had toughened, especially from the largest banks--Morgan, Citibank, Chase, Chemical, Security Pacific, and others that had been aggressive in changing course and developing new resources and expertise.

Because wholesale banking relationships have in the past involved a broad array of varied transactional services, a banking organization such as Bank B has traditionally had many small departments and a high ratio of managers and professionals to clerks. In this bank, nearly 40 percent of the employees are officers and this figure excludes a substantial share of technical personnel just below the officer level.

In the old world of wholesale banking, most employees were hired at a young age, just out of high school level, entered in clerical positions, and learned the ropes of the business as they moved up the ladder. This was a safe way of operating and transferring knowledge as long as banking products and processes were stable.

But changes in corporate banking markets have led to the rapid introduction of new, typically computer-based services, and to a rise in the need for specialists and experts both to develop and sell the new products: system engineers, system analysts, actuarial specialists, security traders, interest swap specialists, currency traders and so forth. This need for "specialists" clashed with the bank's human resource policy which prepared "generalist" managers.

The bank, therefore, had to purchase a corporate cash management system from an outside vendor; it lacked both the expertise and the scale necessary to develop an in-house system and to recruit many specialists on the outside labor market, including system analysts and programmers to work on computerization projects, securities traders to develop its trading department, or human resources and personnel

managers to refocus the whole human resource strategy of the bank. At first, however, the banks saw these as one-time changes.

Over the long run, however, a steadier process of change has been taking shape. For example, the bank has identified the need for sophisticated account officers to manage the relationships with corporate customers. Accordingly, the bank has begun recruiting MBA, for positions as loan officers and credit analysts. The bank complements their training by sending them to take graduate level finance courses and through an 18-month job-rotation program within the bank. However, the bank now staffs software development projects with both in-house personnel and outside specialists hired on a project basis.

Many tensions have resulted from these transformations. The old cadre of managers has found it difficult to hire specialists, often lacking sufficient knowledge of the new specialized skills to pass proper judgment. In addition, the hiring of outside specialists has disrupted the bank's corporate culture by threatening the policy of filling positions from within and of moving employees from clerical to officer positions. Lastly, the bank is unclear about how to integrate new specialists into the work force, and about how to insure that they maintain the right level of expertise--in short, about how to manage the new labor pool.

Lessons. Developments in the banking industry underscore several points. First, the industry is undergoing a fundamental reshuffling of skills and training. These changes are putting enormous pressure on banks to hire, train, or otherwise develop a very different kind of labor force, at very different levels of the occupational structure, than they did ten years ago. Yesterday's bank manager, sometimes with a four-year college degree but often with much less, and with twenty years of experience with the same bank, no longer fulfills the demand for high level skills associated with trading, mergers and acquisitions, swaps, or other complex services. Likewise, yesterday's

high school graduate employed in a platform position no longer suffices to staff bank branches.

Second, the impact of micro-electronics has not been confined to transforming the production process of traditional banking products. Indeed, the impact that computers have had on the development of new banking services and markets has been at least as important as its impact on the reorganization of traditional functions such as the handling of checking and savings accounts.

Third, developments observed in the industry also illustrate differences in the impacts of the technology on various occupational levels. The development of enormous number crunching capacities has eliminated the need for most low skilled jobs. Enhanced communication and information processing linked to the technology's flexibility has led to a broadening of skills for middle level personnel. Technology-related changes in products and markets and the technical requirements for the technology itself resulted in increased specialization among upper level staff.

Fourth, the industry has come to rely more on outside preparation although there has also been an increase in product training and certain kinds of behavioral training that are not provided adequately by the traditional educational system. Middle level positions require higher levels of general education to handle the broader, problem-solving tasks involved. And banks have to go to the market for higher level specialists simply because the required expertise is not available internally.

Finally, the two examples illustrate the importance of institutional factors in constraining the process of adjustment. In both cases, a corporate tradition of internal promotions and a corporate culture that emphasized firm loyalty created tremendous strain in the firms' ability to react to the new environment.

Skill Formation: A Conceptual Framework

This section draws on the banking study, the research on changes in skill levels and more theoretical labor market literature to develop a conceptual framework to help analyze the impact of computer based technologies on the balance of training between the educational system and the workplace. We emphasize four factors that bear on firms' decisions whether to develop skills in-house or to draw them from the external labor market: (1) the availability of skilled labor, (2) uncertainty in labor supply, (3) uncertainty in the firm's product markets, and (4) institutional and social constraints on the firm's behavior. This framework is then used to argue that the role of the outside educational system in work preparation is increasing. At the same time, there appears to be increasing firm specific training in skills and knowledge associated with the firm's need to compete through customization, greater product variety, and better knowledge of markets.

The Availability of Skilled Labor. Firms cannot rely on the labor market for skills unless appropriate skilled labor is available. There are two principal reasons why it may not be available. First, skills may be specific to the firm. This includes knowledge of particular machines, processes or market segments. Since these skills are only useful in one firm, they will not be available in the general labor market. Second, technologies may be so new that a supply of appropriate skilled labor has yet to be developed. How does the introduction of micro-electronic technology in particular affect alter these two labor supply issues? We will review each in turn.

For most labor economists, the distinction between firm specific and general skills is the basis for the analysis of training inside and outside the firms (Becker, 1964; and Doeringer and Piore, 1971). According to this perspective, employers are not willing to invest in general skills since the investment is embodied in workers who can take it with them when they leave. Firm specific skills are another matter.

The firm usually must provide the training, either internally or through an outside vendor, although it can still lose its investment if the worker leaves before the training expense is amortized.

The argument can be made that the micro-electronic technologies are reducing the relative importance of firm specific skills. Micro-electronic technologies do seem to have the potential to standardize many previously idiosyncratic business practices, such as inventory control, accounting, or finance management, so that reliance on workers with extensive firm-specific training and experience is reduced.

In the upper echelons of the occupational hierarchy, there is a rise in expertise requiring concentrated training periods that take place outside individual firms. While this new expertise is not purely the result of the introduction of micro-electronic technology, micro-electronics has contributed to specialization in many areas ranging from engineering and system design to marketing, finance, and planning at the managerial level. Previously these functions were more easily carried out by generalist managers who had less need for higher level outside training.

At lower levels in the employment hierarchy, where long technical training is less important, other factors are pushing firms to rely more on skills and aptitudes acquired outside the firms. To the extent that micro-electronics has allowed workers to take on a broader variety of functions, it places a greater value on an employee's ability to develop an abstract understanding of the production process and its relationship to the goals of the firm. While the specifics need to be taught by the firm, the overall process requires stronger general educational preparation. This is certainly consistent with the rise in minimal entry level educational requirements in the banks and in many other large firms.

Notwithstanding these forces pulling towards greater externalization, the new technology may also encourage internal

training by creating the need for new skills that are simply unavailable in the labor market. In this case, firms will be forced to provide even general skill despite the potential for widespread use outside the firm. Here the differentiation of the effects of technology according to the stages of its diffusion is important. Thus Patricia Flynn (1988) argues that a relationship does exist between the locus of training and the stage of application of a new technology. Firms depend on on-the-job training when new technologies are first introduced. Later, as new technologies spread, skills become more widespread and firms attempt to shift the cost of training to the individual worker or to the outside education system. Nevertheless, during periods of rapid technological change, firms will have to increase internal work preparation.

Still, one can make as strong an opposite argument. New skills may not be available internally, firms may not know how to develop them, and firms may need to go at least to outside contractors or consultants if not to workers trained elsewhere. For that matter, in the earlier example of Bank B the unavailability of internal skills and lack of knowledge about how to develop them were key forces that drew the bank into the external labor market.

The greater diversity of products, proliferation of market segments, and increased customization that have come to characterize the economy of the late 1980s are factors that also create the need for firm specific skills, as the developments described in the banking study illustrate. Insofar as workers must increasingly understand products, customers, and markets that are unique to the firm, the required training must be provided, or at least financed, internally.

Nevertheless, when firms increase internal training, either because the skills are brand new or because of uniqueness of the products, customers, or processes, that internal training is not used to replace outside preparation. Recent research suggests that the increased internal training builds on high levels of outside education

(Lilliard and Tan, 1986). And although Bank B did provide specialized finance training, it did this for MBA holders; it did not use supplemental training to upgrade present employees with lower levels of education. That industries characterized by rapid technological change tend to have more highly educated labor forces (Bartel and Lichtenberg, 1986) is also indicative of greater reliance on abstract knowledge and education.

Uncertainty of Availability of Labor Supply. If skilled labor is simply not available in the labor market, then firms must try to develop needed skills internally through training, or, perhaps can make do with workers who have more or less related skills. In weighing these options, employers must take into account the investment nature of their training expenditures--money is spent now for future returns. As a result, the extent of the employer's uncertainty about future developments in both the labor and product markets is an important influence on training decisions.

Osterman (1986) argues that predictability is a fundamental consideration in choosing among different types of employment systems. He states that

> the modern firm operates as a planning bureaucracy with a fairly long time horizon. In order to plan output and set prices in advance it must be confident of assured supplies and knowable prices. In this context it matters less if the price of labor is high or low as long as it is known with some assurance. (p. 14)

This type of consideration, Osterman suggests, will favor internal training ladders and in-house training programs since costs and availability of skills will be more subject to the firm's control.

Uncertainty in the Firm's Market. While uncertainty in the labor market encourages internal training, uncertainty in product markets has the opposite effect. In a market environment characterized by rapid

change, long-term predictability of the availability and cost of the labor force is not useful if it implies long-term commitments or investments that are amortized over long periods. In these circumstances firms might prefer to maintain their flexibility and increase their reliance on the skills available from the labor market. Alternatively, they could seek workers with an abstract understanding of the technologies and processes they use in production rather than concrete understanding, based on firm specific experience, that becomes obsolete with each technological change. Once again, this entails greater reliance on outside schooling in that it implies higher educational requirements for entry into the firm.

To some extent, a period of uncertainty both in labor and product markets accompanies the early diffusion of any major technological innovation. Nevertheless, it does appear that micro-electronics will continue to generate rapid change and accompanying uncertainty well into the next century. It is safe to say that, the on-going drop in costs and changes in both hardware and software will continue to generate an expansion of applications throughout the economy. As a result, there is a long-term rather than just a short-term increase in uncertainty, and this will continue to put pressure on firms to externalize their training.

Institutional Constraints. Whatever the optimal training response to changing skill requirements, firms face a variety of institutional and organizational constraints. Contractual provisions controlling layoffs and promotions, customary procedures and norms, government regulations, corporate culture, and organizational and management capacity all limit the firms' freedom to adjust their human resource strategies. These constraints can reverse expected adjustments to technological change. For example, rapid technologically induced change in output markets might be expected to encourage employers to reduce expensive internal training efforts and to look to the outside market for skilled workers. But to the extent that legal or social and customary factors prevent employers from dismissing workers with

obsolete skills, rapid change will induce greater internal training as employers try to prepare their current labor force for the new environment.

On the other hand, these institutional factors that bind together workers and firms are themselves influenced by technological change. Micro-electronics, in conjunction with other factors, through its influence on markets and competition, and through its tendency to reduce the importance of firm specific skills and to increase the pace of change and level of uncertainty, has undermined the strength of unions, the development of informal customs and company culture, and the general economic conditions on which long-term relationships between firms and workers are based.

In conclusion, micro-electronics is increasing the relative role of the education system in work preparation both by increasing the importance of general skills and by increasing the endemic uncertainty in the market environment in which firms must operate. At the same time, the proliferation of products and greater customization of output has resulted in an expansion of internal training. But where increased firm-based training is necessary, it complements rather than replaces higher levels of general education. Finally, while institutional and social constraints do slow down the shift towards externalization, the new technology itself weakens the institutions and processes on which those constraints are based.

Conclusions

Most recent research on the impact of the new computer technology on skills has been focused on developing arguments that either support or contradict the "deskilling" thesis put forth by some economists and sociologists in the mid and late 1970s. Although this research remains inconclusive, our reading of the literature, as well as the results of our own forays in the banking industry, suggests some generalizations.

In evaluating the research, it is essential to take into account the stages of introduction of the new technology.

At least in the large core firms in both manufacturing and services, micro-electronics is eliminating rather than increasing the lowest skilled jobs. To the extent that the number of such jobs is growing, they are doing so outside of the large firms either in auxiliary industries, such as food service, or perhaps in small subcontracting firms. The banking example also supports findings from some studies of both large white collar and some manufacturing industries that micro-electronics enables the broadening of skill requirements for middle level jobs. And the banking case in particular illustrates that the introduction of computer-based technology leads to greater specialization of upper level and managerial personnel.

Surprisingly, however, the large body of research on employment and technology has little to say about the impact of micro-electronic technology on the process of skill formation. Evidence from the banking study indicates, however, that in this industry at least the processes of skill formation are undergoing a major transformation, suggesting both an increasing role for outside educational preparation and a build-up in firm-based training for highly specific objectives.

In order to lay the foundation for further study of this transformation in the skill formation process and its relationship to the new technology, this paper developed a framework that emphasizes the relationship between the development and diffusion of the new technology and the availability of skilled labor, the uncertainty in labor supply and the firm's markets, and the institutional and social factors that shape firm's response. The stages of the development and diffusion of the new technology must also be considered here. Preliminary analysis based on this framework suggests that the changes in the skill formation process that we observed in the banks are indeed more general phenomena.

The use of computer-based processes has the potential to produce widespread positive effects in our standard of living and in the nature of work. But more than previous shifts in production techniques and processes, the efficient and socially healthy introduction and adaptation of these new processes depends fundamentally on the development of an appropriate skill formation process for all levels of the work force. As we have emphasized throughout this paper, this is not simply a question of more or fewer skills but rather one of changing skills and one of a new balance in the process of skill formation between education institutions and the work place. While other researchers have devoted much attention to the issue of skill effects, our research described here, part of a longer-term project, is designed to help open a more intensive study of the changing skill formation process.

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